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APPLICATION OF MULTIPLE REGRESSION ANALYSIS TO STUDY THE RELATIONSHIP BETWEEN EEG RHYTHMS AT PERSONS WITH MENTAL RETARDATION

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Abstract

Using the calculation of coefficients of multiple linear regression of two-dimensional correlation, we studied the mutual influences (functional connectivity) between the amplitudes of EEG rhythms in people with mental retardation. Multiple regression equations were geometrically interpreted using polycyclic multigraphs. As a result of the studies and calculations, it was found that in mental retardation, the number of regression coefficients of the two-dimensional correlation is determined to be greater than in the norm. In the sinistrals control group, the coefficients of multiple regression of two-dimensional correlation were determined more than in the dextrals control group. In mentally retarded sinistrals, the number of multiple regression coefficients was determined to be less than in mentally retarded dextrals, but the number of bivariate correlation coefficients was larger. The resulting

increase in correlation coefficients may indicate an increase in tone in sinistrals suffering from mental retardation compared to dextrals with mental retardation. The mechanism of this increase in tone is realized by linear functions.

Key words: mental retardation; multiple regression; polycyclic multigraphs; hemispheric differences.

Introduction. The leading role in the work of the brain should be played by dynamic functional connections between different parts of the cortex and subcortical structures, and the problem of intercentral relationships of biopotentials occupies one of the leading places [1]. According to M. N. Livanov "Already a priori, one can think that the conjugation-similarity of the flow of biopotentials of points of the brain substrate remote from each other indicates the presence of interdependence between them. Of course, these mutual influences can be both direct and indirect [5].

The formation of a functional connection between brain regions can be judged by the synchronization of their electrical activity [10, 20]. For these purposes, the calculation of the two-dimensional correlation coefficient is used. Coherence (relationship) analysis evaluates the level of covariance of the spectral measures obtained for any pair of electrodes. Coherence is considered to be a witness to the structural and functional connections between areas of the cerebral cortex. This method is well established as a method used to quantify hemispheric connections across the corpus callosum in both awake and sleeping patients.

The study of coherence is based on the concept created by M. N. Livanov of the spatio-temporal organization of the bioelectrical processes of the brain. The basis of the method is the calculation of the two-dimensional correlation coefficient between potential fluctuations recorded in different cortical zones.

However, with this approach, it is impossible to determine the direction of influence, because correlation coefficient Rx/y=Ry/x/. With this approach, there is no method for synthesizing objects of system analysis. In addition, the application of the correlation coefficient establishes a relationship between concepts of one of two main types: covariance or causation. There is also the problem of imaginary relationships. Only causal relations are informative.

In addition, coherence studies were often carried out using only two pairs of electrodes (Fz-P3иFz-P4) [18].

Considering brain electrogenesis as a systemic category, i. e. "a set of elements that are in certain relationships with each other and with the environment", it becomes necessary to study the connections-relationships, i.e. connections directed from one object to another, formed between individual indicators of electrogenesis, which are set by the results of EEG analysis (amplitudes, frequencies, EEG rhythm duration indices).To solve the problem, you can use the classical methods of mathematical statistics: multiple regression and correlation methods of analysis. When using this method of analysis, all the obtained connections-relations are oriented, that is, directed from one object to another, direct (not indirect).

In recent years, the role of neural networks in the structure of brain activity has become increasingly clear. Interindividual differences at any level (genetic, environmental, etc.) are manifested in the organization of neural networks, and a systematic approach is needed to analyze and understand them [7]. Graph theory, as an example of such a systematic approach, turns out to be a useful tool for network analysis of various neuroimaging data (EEG, MEG, fMRI) [12, 14].

The system approach is based on the study of the properties of the whole as a whole. A possible way to solve the problem of synthesizing objects of multidimensional research is the geometric interpretation of multiple linear regression equations using polycyclic multigraphs - a mathematical language for a formalized designation of concepts related to the analysis and synthesis of structures, systems and processes - with the aim of their subsequent structural analysis.

We consider the relationship between EEG rhythms as an important system-organizing factor of electrogenesis. Therefore, having studied the system of oriented connections-relations, i.e. connections-relations directed from one object to another, it is possible to assess the functional state of the EEG, and, apparently, to understand the genesis of the EEG as a system of relations of the activity of neuronal structures of the brain. According to our ideas, the electrical activity recorded in certain regions of the cerebral cortex and subcortical structures is undoubtedly connected, and possibly it is a function, of the electrical activity recorded in other regions of the cerebral cortex and subcortical structures. Therefore, the identification of oriented, i.e. directed from one region of the cortex or subcortical structures to another, connections-relationships can help expand our understanding of the functional state of the central nervous system [6].

EEG coherence was studied in a group of normal children and in a group of children with mild mental retardation at rest with eyes closed. For resting EEG, coherence was higher in children with mental retardation and a slight increase with age was found. [17]. Besthorn et al. [11] studied 50 patients with dementia and found decreased coherence in theta, alpha, and beta bands compared to controls in the central and frontal regions. Their results were comparable to those of Locatelli et al., who showed decreased coherence in alpha dementia in the left temporo – parieto - occipital region. It has been shown that low coherence is positively correlated with IQ and is a predictor of IQ. This indicates that the more complex the neural network, the higher the spatial differentiation, the lower the coherence between different neural pathways [thirteen]. We studied the power and coherence of electroencephalography (EEG) at rest and during the performance of a working memory task in patients with mild cognitive impairment. It was found that all EEG power and coherence values in patients with mild cognitive impairment were higher than in normal controls at rest and during working memory tasks. This suggests that mild cognitive impairment may be associated with compensatory processes at rest and during working memory tasks. According to the author, in patients with mild cognitive impairments, there may be a violation of normal cortical connections [21].

Functional interhemispheric EEG asymmetry is currently recognized as one of the basic neurophysiological mechanisms of the brain. Currently, to study functional interhemispheric asymmetry, the most commonly used linear fractional function of the form (L-P) / (L + P) * 100 and the study of coherence. It is interesting to use multiple regression analysis to study interhemispheric asymmetry.

It should be noted that the study of neurodynamic mechanisms in mental retardation was not carried out in the mode of periodometric analysis of EEG mapping. At the same time, this technique of computer electroencephalography is one of the most informative [9] and promising in terms of identifying pathognomonic electroencephalographic features.

Therefore, the puprose of our work was:

1. To investigate the EEG in mentally retarded persons using half-period analysis.

2. Using multiple regression and two-dimensional correlation analysis to investigate the relationship between EEG rhythms in all leads and in all ranges of the EEG in mental retardation in comparison with the control.

3. To study the functional interhemispheric asymmetry of the EEG rhythm amplitudes in mental retardation using multiple regression analysis.

4. Compare the results of evaluating the relationship between EEG rhythms using multiple regression and correlation methods of analysis and two-dimensional correlation angalization.

5. Build graphs reflecting the relationship between EEG rhythms and analyze them.

Material and methods. 65 patients diagnosed with mental retardation (according to ICD - 10 heading F 70) aged 16 - 18 years were examined - the main group who were on inpatient examination and treatment at "The Odessa Regional Mental Health Center", (Ukraine). The control group consisted of 34 people aged 16 - 24 y. o. The EEG was recorded in a state of calm wakefulness with closed eyes on the Neuron-Spectrum-2 electroencephalograph at a quantization frequency of 500 Hz using a montage: bipolar ring 16.

The electrodes were placed according to the "10-20%" system in l6 cortical zones. EEG recording was carried out according to the international system "10%–20%" [23] from the frontal (F3, F4), central (C3, C4), parietal (P3, P4), occipital (01, 02), anterior temporal (F7, F8), middle temporal (T3, T4) and posterior temporal (T5, T6) cortical zones (odd numbers indicate areas of the left hemisphere, even numbers - right). A bipolar ring assembly was used 16. The bandwidth was 0.5-35 Gy, the sampling frequency was 500 Hz.

The analysis was performed using periodometric analysis in five standard frequency ranges:

σ 0.5–4 Hz. Θ 4-8 Hz,. α 8 \u003d 13 Hz, β1 13-20 Hz, β2 20-32 Hz.

Differences in performance were tracked using the calculation of ratio coefficients (RC). CS was obtained by dividing the larger value of the compared indicators by the smaller one [6].

Each of the set of indicators selected for analysis (amplitudes and frequencies of EEG rhythms) was considered as a target feature (Y-s), and the remaining indicators were considered as influencing variables (sets of X-s) and equations of multiple linear regression of the form:

$$Y1=a_0+b1X1+b2X2\ldots+bnXn,$$

where a_0 is a free member, coefficients b1,b2…., bn are regression indicators reflecting the degree of influence on the analyzed indicator of the remaining elements of the set, x1, x2…, xn indicators. The probability of manifestation of influence, i. e., the adequacy of the regression coefficients, was assessed using the sigmal deviations of the regression coefficients, and the effectiveness of the regression as a whole was assessed by calculating the multiple correlation coefficient [8]. One of the possible ways to solve the problem of synthesizing objects of multidimensional research is the geometric interpretation of multiple linear regression equations using polycyclic multigraphs [4].

Own research. With multiple regression and correlation analysis of the mutual influences of the amplitudes of the same rhythms in both hemispheres, the total number of statistically significant regression coefficients in the main group was 1.63 times greater than in the control group (Table 1). In the delta and theta ranges in the main group, the number of regression coefficients was less than in the control group, and in the beta-LF and beta-HF ranges - more. Only in the alpha range of the EEG, the coding of statistically significant regression coefficients was the same in both the control and main groups. The number of two-dimensional correlation coefficients (Table 1) between the amplitudes of the same rhythms in both hemispheres in the main group was 1.14 times greater than in the control group. Only in the EEG delta rhythm range, the two-dimensional correlation coefficients were lower in the main group than in the control group, and higher in all other ranges.

With multiple regression and correlation analysis of the mutual influences of the frequencies of the same rhythms in both EEG hemispheres (Table 2), the total number of statistically significant regression coefficients in mental retardation was determined 1.22 times more, and the two-dimensional correlation coefficients 1.48 times more than in the control group.

Table 1

Statistically significant regression and correlation coefficients between EEG rhythm amplitudes

Rhythms EEG	Number of coefficients			
	Regressions		Correlations	
	К	MR	К	MR
	75	82	93	83
Delta	61	104	102	118
Theta	56	56	95	107
Alpha	31	85	75	89
Beta LF	31	86	58	84
Beta HF	254	413	423	481

Comment: K-control group, MR-basic

Table 2

Statistically significant regression and correlation coefficients between EEG rhythm frequencies

Rhythms EEG	Number of coefficients			
	Regressions		Correlations	
	К	УО	К	УО
Delta	32	41	44	83
Theta	34	42	84	105
Alpha	29	44	29	66
Beta LF	32	30	22	40
Beta HF	38	44	49	45
Total	165	201	228	339

Comment: K-control group, MR-basic

Thus, between the amplitudes (Fig. 3) and frequencies (Fig. 4) of EEG rhythms in the mentally retarded, more coefficients of multiple regression and two-dimensional correlation are revealed.

In order to assess lateralization in mental retardation, we calculated the coefficients of multiple regression and correlation between the amplitudes of the same EEG rhythms within the same hemisphere, left and right in right-handers and left-handers in the main and control groups. For this purpose, we used the constructed polycyclic multigraphs that visualize the relationship between EEG rhythms in right-handed and left-handed people in the control group and in mentally retarded people in the left (Fig. 1) and right (Fig. 2) leads.

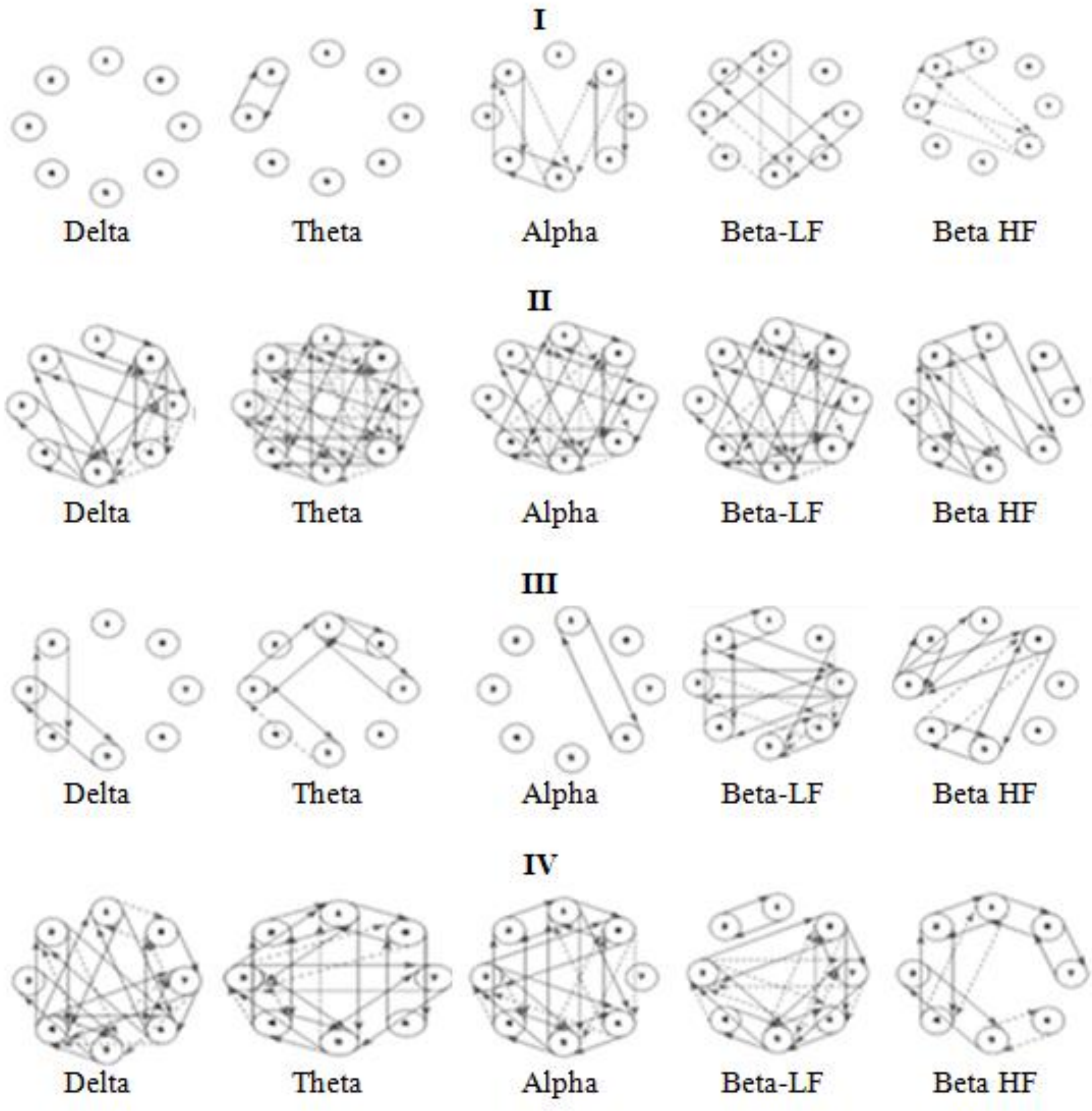

Fig. 1. Polycyclic multigraphs reflecting the relationship of EEG rhythms in the control group and in the mentally retarded in the left hemisphere.

Comment: I-Right-handers, control, II-Right-handers, mentally retarded, III-Lefty-handed, control, IV-Lefty-handed, mentally retarded. 1-C3-P3 Central-parietal, 2-F3-C3 Frontal-central 3-F7-T3 Temporal-central, 4-FP1-F3 Frontal, 5-FP1-F7 Anterior-temporal, 6-P3-O1 Parietal-occipital, 7-T3-T5 Posterior-temporal, 8-T5-O1 Temporoccipital. Solid lines are positive influences, dashed lines are negative ones.

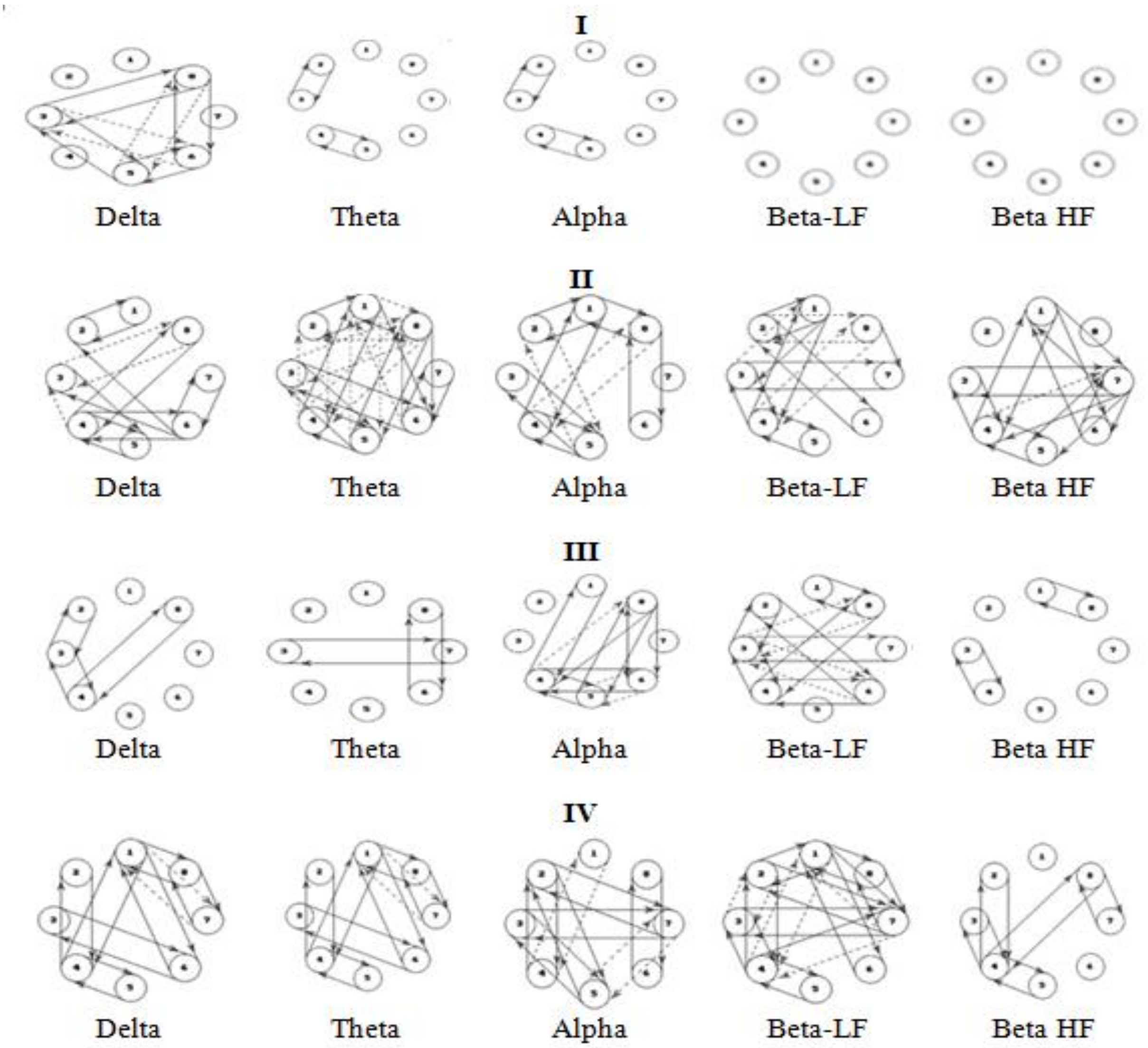

Fig. 2. Polycyclic multigraphs reflecting the relationship of EEG rhythms in the control group and in the mentally retarded in the right hemisphere.

Comment: I-Right-handers, control, II-Right-handers, mentally retarded, III-Lefty-handed, control, IV-Lefty-handed, mentally retarded.1-C4-P4 Central-parietal, 2-F4-C4 Fronto-central 3-F8-T4 Temporal-central, 4-FP2-F4 Frontal, 5-FP2-F8 Anterior-temporal, 6-P4-O2 Parietal-occipital, 7-T4-T6 Posterior-temporal, 8-T6-O2 Temporoccipital.

As can be seen from the figure, in the mentally retarded, both left-handed and right-handed, the number of regression relationships was greater than in the control group. In right-handers and left-handers, the most distinct increase in regression coefficients was noted in the delta, theta and alpha ranges. When calculating the coefficients of multiple regression in the control group of right-handers (Table 3), it turned out that in the left hemisphere the regression coefficient is higher than in the right, 28 and 22, respectively, and the two-dimensional correlation coefficients are higher in the right hemisphere than in the left 40 and 30, respectively. Multiple regression coefficients were determined more in delta and alpha rhythms in the right hemisphere, and in theta in beta-low-frequency and beta-high-frequency rhythms in the left hemisphere.

Table 3

Statistically significant regression and correlation coefficients between EEG rhythm amplitudes in the control group of right-handers

EEG rhythms	Number of coefficients			
	Regressions		Regressions	
	L	R	L	R
Delta	0	12	3	2
Theta	10	4	5	12
Alpha	2	6	3	6
Beta LF	8	0	9	5
Beta HF	8	0	10	15
Total	28	22	30	40

In the left-handed control group (Table 4), more regression coefficients were determined in the left hemisphere than in the right 47 and 44, respectively, and two-dimensional correlation coefficients were also determined in the left hemisphere than in the right 80 and 53, respectively. In the delta, alpha and beta low-frequency ranges, a greater number of regression coefficients was determined in the right hemisphere, and in the theta and beta high-frequency ranges in the left.

Table 4

Statistically significant coefficients of regression and correlation between the amplitudes of EEG rhythms in the control group of left-handed people

EEG rhythms	Number of coefficients			
	Regressions		Correlations	
	L	R	L	R
Delta	4	6	10	10
Theta	15	4	25	19
Alpha	2	14	18	8
Beta LF	14	16	5	7
Beta HF	12	4	22	9
Total	47	44	80	53

Solid lines are positive influences, dashed lines are negative.

Comparing right-handers and left-handers of the control group, it can be noted that left-handers had more regression coefficients in both the left TPC and in the right hemispheres than right-handers by 1.68 and 2 times, respectively, and two-dimensional correlation coefficients by 2.66 and 1.33 times, respectively. (Fig. 3).

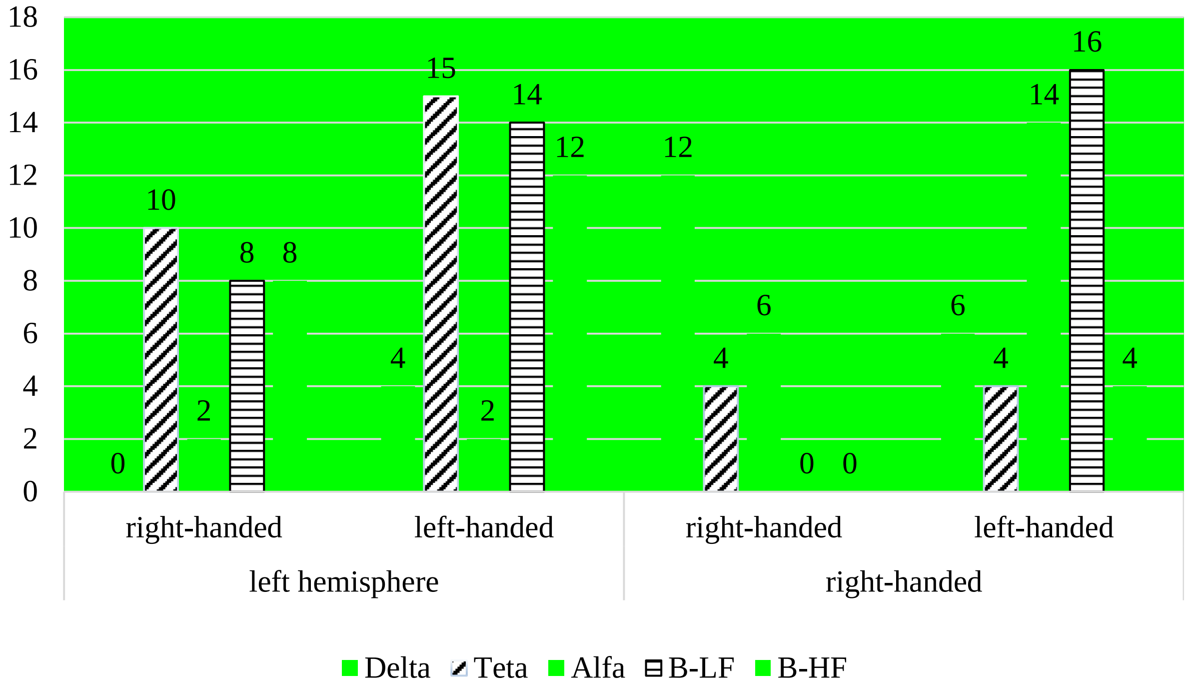

Fig. 3. Statistically significant regression coefficients between the amplitudes of EEG rhythms in dextrals and sinistrals control groups.

Comment: Left - left hemisphere, right - right hemisphere.

In mentally retarded right-handers (Table 5), as well as in the control group, a greater number of regression coefficients were determined in the left hemisphere than in the right 131 and 102, respectively, and two-dimensional correlation coefficients in the right hemisphere were determined more than in the left 63 and 42, respectively.

In the delta, theta, alpha and beta low-frequency ranges, the regression coefficients were determined more in the left hemisphere than in the right in the beta low-frequency range - in the right.

The number of regression coefficients was determined to be greater in mentally retarded dextrals than in the control group in the left hemisphere by 1.68 times and in the right by 1.64 times. The coefficients of two-dimensional correlation in persons suffering from mental retardation were also determined more than in the control group in the left hemisphere by 1.4 times and in the right by 1.56 times.

Table 5

Statistically Significant Regression and Correlation Coefficients Between EEG Rhythm Amplitudes in Mentally Handicapped Right-Handers

EEG rhythms	Number of coefficients			
	Regressions		Regressions	
	L	R	L	R
Delta	22	18	10	17
Theta	38	30	24	18
Alpha	28	16	0	0
Beta LF	28	22	0	19
Beta HF	15	16	8	9
EEG rhythms	131	102	42	63

In mentally retarded sinistrals (Table 6), as well as in mentally retarded dextrals, a greater number of regression coefficients were determined in the left hemisphere than in the right 116 and 82, respectively, and the number of two-dimensional correlation coefficients was determined more in the right hemisphere than in left - 109 and 101, respectively. In all EEG ranges, more regression coefficients are determined in the left hemisphere than in the right.

Table 6

Statistically Significant Coefficients of Regression and Correlation Between EEG Rhythm Amplitudes in Mentally Handicapped Sinistrals

EEG rhythms	Number of coefficients			
	Regressions			
	L		L	
Delta	28	16	13	22
Theta	22	18	21	26
Alpha	26	16	25	18
Beta LF	26	25	21	21
Beta HF	14	7	21	22
EEG rhythms	116	82	101	109

Comment: L - left hemisphere, R - right hemisphere.

As well as in mentally retarded right-handers, in mentally retarded left-handers, the number of regression coefficients was determined to be 2.46 times greater in the left hemisphere and 1.86 times greater in the right hemisphere than in the corresponding control group. The number of two-dimensional correlation coefficients was also determined to be greater in the group of mentally retarded sinistrals than in the control group in the left hemisphere by 1.26 times, in the right - 2.06 times.

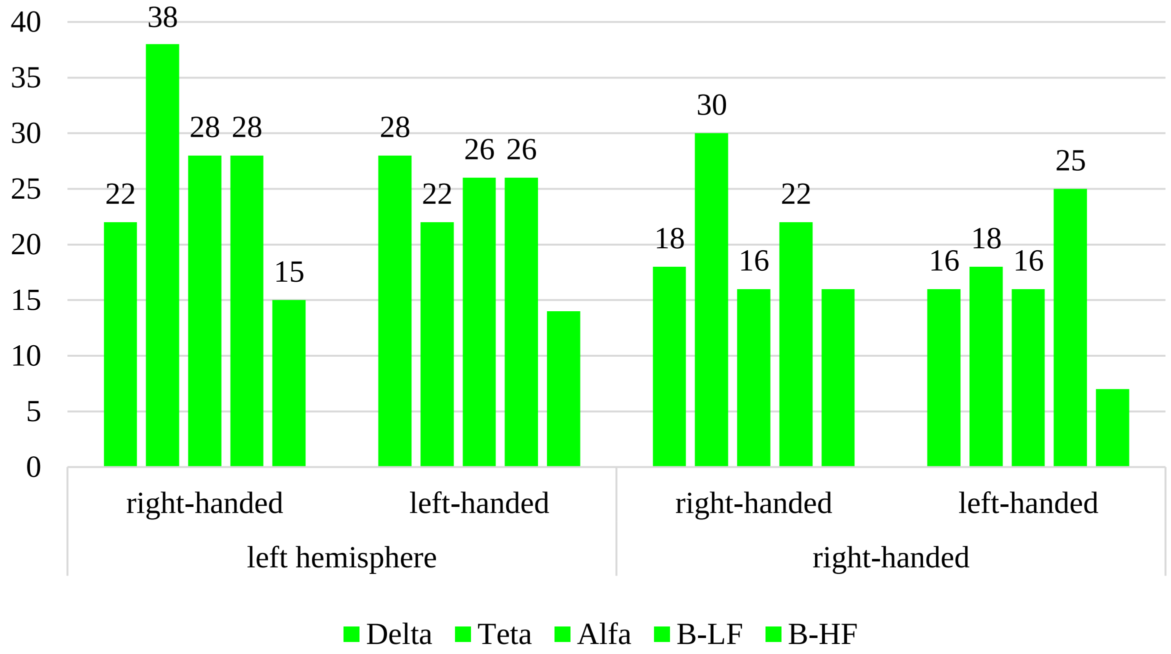

Fig. 4. Statistically significant regression coefficients between the amplitudes of EEG rhythms in dextrals and mentally retarded sinistrals.

Comment: Left - left hemisphere, right - right hemisphere.

Comparing right-handers and left-handers of the mentally retarded, it can be noted that, unlike the control group, the number of statistically significant regression coefficients in sinistrals was less than in dextrals, but the number of correlation coefficients, such as in the control group, was greater in sinistrals.

Discussion

Multiple regression and correlation analysis of the mutual influences of the amplitudes of the same rhythms and frequencies in both hemispheres in persons suffering from mental retardation revealed more of both the multiple regression coefficient and the two-dimensional correlation coefficients. Perhaps this is due to the formation of a system of compensatory neurophysiological mechanisms in persons suffering from mental retardation [21].

The largest number of regression coefficients in the control group was determined in the delta range, and in the main group in the theta range. The largest number of correlation coefficients in both the control and main groups was determined in the theta range. In all EEG ranges, with the exception of the alpha rhythm range, the number of multiple regression coefficients was determined to be greater in the mentally retarded than in the control group. In the alpha rhythm range, the number of multiple regression coefficients in the control and main groups was determined to be the same. This may indicate that the system generating the alpha rhythm in persons suffering from mental retardation is damaged to a greater extent than the systems generating other EEG rhythms and becomes incapable of forming compensatory reactions.

When calculating the coefficients of multiple regression and two-dimensional correlation between the amplitudes of EEG rhythms in the control group in right-handers, it turned out that the regression coefficients were more determined in the left hemisphere, and the two-dimensional correlation coefficient - in the right. This may indicate that different mathematical functions are oriented towards different neurophysiological functions.

The largest number of multiple regression coefficients in right-handers in the left hemisphere was determined in the range of theta rhythm, and in the right hemisphere - in the delta rhythm. The largest number of two-dimensional correlation coefficients, both in the left and right hemispheres, was determined in the beta low-frequency range.

In the sinistrals control group, both multiple regression coefficients and two-dimensional correlation coefficients were determined more than in the dextrals control group.

According to Rusinov's school of thought [1], an increase in the number of correlations between various EEG components reflects an increase (in general) in cortical tone, while a decrease reflects a decrease in this tone. It can be assumed that in sinistrals, in comparison with dextrals, the tone of the cortex is increased.

When studying the coherence function of healthy dextrals in a state of calm wakefulness, most studies note the advantages of the degree of synchronization of the alpha rhythm as the most informative criterion for the functional interconnection of cortical structures in the left hemisphere [2, 3]. Along with this, there is also evidence that dextrals people have large coherence values in the frontal areas of the brain of the right hemisphere for alpha and beta-2 ranges when analyzing interhemispheric and for delta and theta intrahemispheric ranges [19].

In the studies of Boldyreva G.N. et al. [2, 3] using the analysis of EEG coherence, aspects of the synchronization of electrical processes in the left and right hemispheres of the brain in healthy dextrals and sinistrals in a state of calm wakefulness were studied. Dextrals showed greater coherence in the left hemisphere, while sinistrals showed greater coherence in the right hemisphere. Differences were also observed between dextrals and sinistrals in the regional profiles of interhemispheric asymmetry and in the interhemispheric asymmetry of individual spectral bands. The authors believe that these differences may reflect variations in the involvement of cortical and subcortical structures of the brain in the formation of hemispheric specificity. Certain characteristic regional patterns of interhemispheric asymmetry and asymmetry in the spectral ranges seem to be necessary for the normal functioning of the human brain [3].

Flor Henry et al. [16] found higher values of intrahemispheric coherence for the beta-2 range in the right hemisphere in right-handers in a state of calm wakefulness when assessing intrahemispheric coherences in a conventional way, that is, when comparing coherences in homologous pairs within each of the hemispheres.

In our studies, a greater number of regression coefficients for both right-handers and left-handers of the control group was determined in the left hemisphere. A greater amount of two-dimensional correlation in right-handers was determined in the right hemisphere, and in left-handers in the left.

When calculating the correlation coefficient, strictly linear relationships are determined, and when calculating the coefficients of multiple regression, both linear and non-linear relationships are calculated. It can be assumed that the interaction of brain structures is realized both in terms of linear and non-linear functions.

Studies of EEG functional connectivity associated with handiness are few and poorly comparable. Thus, when using only two pairs of electrodes (Fz-P3 and Fz-P4) in the interhemispheric coherence of the EEG in the alpha range, opposite changes were found between the conditions of rest and the spatial imaginary task [18].

When calculating the coefficients of multiple regression and two-dimensional correlation between the amplitudes of rhythms in left-handers, it turned out that the coefficients of multiple regression and two-dimensional correlation coefficients are greater in the left hemispheres than in the right ones.

In left-handers, the largest number of regression coefficients in the left hemisphere was determined in the theta, beta low-frequency range, and in the right hemisphere in the beta low-frequency range.

In the group of mentally retarded right-handers, the number of regression coefficients in the left hemisphere was determined to be greater than in the right. There were more coefficients of two-dimensional correlation in the right hemisphere than in the left. These correlations were also found in the dextrals control group. This may indicate the safety of the studied mentally retarded neurophysiological mechanisms that ensure the implementation of linear and non-linear connections and relationships.

The largest number of regression coefficients in the group of mentally retarded right-handers was determined in the theta range, both in the left and right hemispheres. The largest number of correlation coefficients in the left hemisphere was determined in the range of theta rhythm, and in the right - in the beta low-frequency rhythm. In the control group of right-handers, the largest number of regression coefficients was determined in the theta range of the left hemisphere and the delta range of the right hemisphere. The largest number of two-dimensional correlation coefficients was determined in the high-frequency beta range. The obtained differences may indicate a special functional significance of the theta rhythm in the neurophysiological provision of the mentally retarded.

The largest number of regression coefficients in the group of mentally retarded left-handers was determined by the left hemisphere in the delta rhythm range, and in the right beta low-frequency rhythm. The largest number of two-dimensional correlation coefficients was determined in the left hemisphere in alpha, and in the right - in theta rhythm. In the control group of left-handers, the largest number of regression coefficients was determined, as well as in right-handers of the control, in the theta range, and in the right hemisphere in the beta low-frequency range. The largest number of two-dimensional correlation coefficients was determined in the theta range both in the left and in the right hemispheres. The obtained differences may indicate a special role of alpha-rhythm synchronization in mentally retarded people in the formation of compensatory mechanisms.

In the group of mentally retarded left-handers, the number of regression coefficients was determined to be less than that of right-handers, but the number of correlation coefficients was greater. The resulting increase in correlation coefficients may indicate an increase in tone in left-handers suffering from mental retardation compared to right-handers suffering from mental retardation, and the mechanism of this increase in tone is realized by linear functions.

Conclusions:

1. Between the amplitudes and frequencies of EEG rhythms in mental retardation persons a greater number of multiple regression coefficients and two-dimensional correlation coefficients were detected. Perhaps this is due to the formation of a system of compensatory neurophysiological mechanisms in persons suffering from mental retardation.

2. In the control group of left-handers, both multiple regression coefficients and two-dimensional correlation coefficients were determined more than in the control group of dextrals. It can be assumed that in sinistrals, in comparison with dextrals, the tone of the cortex is increased.

3. A greater number of regression coefficients for both dextrals and sinistrals was determined in the left hemisphere. A greater number of two-dimensional correlation coefficients in dextrals was determined in the right hemisphere, and in sinistrals. This

suggests that the calculation of multiple regression coefficients and two-dimensional correlation coefficients reveals different aspects of electrogenesis.

4. The topographic difference in the number of multiple regression and two-dimensional correlation coefficients identified in the calculations suggests that the interaction of brain structures is realized both in terms of linear and non-linear functions.

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